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Universidad Carlos III de Madrid
Calle Madrid, 126
28903 Getafe (Spain)
FAX (34) 91 624-95-74

MORE THAN ORE: MODERN SPANISH STEEL, 1856-1936[†]

Stefan Houpt *

Abstract

Contrasting the iron law of the principle of comparative advantages as the determinant of the international division of labour has attracted dissidents to the international trade paradigm over the years. Spanish Bessemer steel is an outstanding comparative advantage enigma which stands to be resolved. Spain possessed important reserves apt for ore specific Bessemer processing. Depletion of existing deposits in industrial Europe and the increasing demand for this resource endowment made this all the more relevant. This paper examines if Spain could have or should have become one of Europe's major producers of Bessemer steel.

Keywords: Spain, iron and steel industry, competition, total factor productivity

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* **Stefan Houpt**, Departamento de Historia Económica e Instituciones, Universidad Carlos III de Madrid.
E-mail: shoupt@clio.uc3m.es

Introduction.

Classical economic theory defends the view that comparative advantage is the optimal criterion for defining a nation's role in world economy. This trade paradigm has consistently been scrutinised by 'new directions' of international trade theory seemingly more appropriate for backward countries catching up from the periphery. Deteriorating terms of trade, economies of scale and scopes, increasing returns and the depletion of natural resources are all issues that developmentalists have launched against the bulwarks of free trade: international specialisation and the principle of comparative advantage. The study of Spain's iron ore extraction and transformation throughout the end of the nineteenth century and the beginning of the twentieth century may provide some empirical evidence to this discussion. Spain was a part of Europe's economic periphery throughout the eighteenth, nineteenth and most of the twentieth century. Its economy —at the time of industrial revolution in most of northern Europe— can be described as backward and predominantly agricultural.[1] The liberalisation of Spanish mining legislation from 1868 on and the quest of developing nations in Europe for resources abroad allowed for important foreign mining investments in Spain in the latter half of the nineteenth century. Copper, mercury, zinc, lead, sulphur and iron ore were the more important minerals to be exploited. The rapid diffusion of the Bessemer steel process from 1862 on made foreign mining interests pick up particularly in the Bilbao area, which had large coastal opencast iron ore reserves. The high quality of northern Spanish iron ores —both in terms of ore grades and low phosphorus content— made iron producers from all over Europe consider securing Spanish ore as part of their long-term firm strategies[2]. Local mine capitalists complemented these international activities by feeding foreign markets with phosphorus low hematite well up to the 1920s. Spain ended up exporting the major part of its rich hematite ore reserve instead of developing an autochthonous iron and steel industry based on these exhaustible resources. Given that the Bessemer process converts pig iron to steel with virtually no coal consumption it is hard to understand why Spain did not develop an industry of its own, based on the high quality and plentiful resource it possessed. Building up on these resources, Spain, more than any other nation in Europe at that time, had a potential comparative advantage for producing Bessemer steel.

Unravelling the reasons why Spanish iron and steel never came to fully exploit this potential may contribute to the discussion on the validity of the principle of comparative advantage for allocating nations roles in international economy and may render some insight on the degree of applicability of international trade theory to backward countries in the periphery. To this end, the first part of this review of Spanish steel will introduce the nineteenth century scenario giving an overview of its more important characteristics up to the era of steel. Section two will examine the feasibility of establishing and running modern integrated mills in Spain and provide empirical evidence to contrast their viability. The final part of this analysis will go on to redefine Spain's industrial backwardness in the context of present day historiography and conclude how existing classical trade theory ought be applied to this case.

Modernisation of Spanish iron during the nineteenth century.

Technical and organisational change in iron and steel processing brought about important long-term increases in productivity throughout the nineteenth century and beginning of the twentieth century. These gains in productivity were attained through three parallel developments: by reducing the cost of heat through a better co-ordination of the successive stages of transformation, by increases in scale that improved energy efficiencies and by a better calibration of processes and procedures that reduced redundancies and waste. A greater part of these achievements was obtainable only after combining the different stages of transformation into large mills were observation, cost accounting and new management techniques helped implement these new techniques.

By definition, modern integrated production of iron —as later that of steel— implied combining coke blast furnaces with puddling facilities for producing wrought iron —later these were replaced by steel processing installations— and rolling mills.[3] In many cases integration included backward integration into coal and iron ore mining, transportation and coal coking and forward integration into product distribution and metal transformation industries. Neither of these additional degrees of integration was strictly necessary for attaining the productivity gains we have mentioned before, they are more concerned with guaranteeing input regularity and markets.

The patterns of these nineteenth century technical and organisational innovation in the Spanish iron industry have been analysed in depth by Luis María Bilbao (1988). He has observed that innovative Spanish iron producers adopted a continental pattern of modernisation similar to that of Germany and France. Spanish mill owners innovated more heavily in the less expensive secondary refining techniques —such as puddling and rolling mills— and improved existing primary transformation processes —such as charcoal blast furnaces or more traditional processes for obtaining raw iron— very late on. Their early reluctance to adopting coke blast furnaces was motivated by the higher relative cost of the investment, its scale dependency and the technical difficulty of calibrating input ratios to obtain an equal quality product to that of their former charcoal based processes. Improving refining techniques and final transformation was less costly in relative terms. It did not depend on such a high throughput volume in order to write off the investments incurred and at the same time these improvements were guaranteed to increase the quality of final output

A second aspect of the industry's pattern of change in Spain has been elaborated by Emiliano Fernández de Pinedo (1985) based on earlier work by Jordi Nadal.[4] Both have identified technical changes, which altered the composition of raw materials used in best practice technology, as determining shifts in regional supremacy throughout the nineteenth century. The shift from direct processing systems for obtaining wrought iron to indirect systems, a second shift from charcoal to coke blast furnaces and a final shift from puddling iron to Bessemer steel using foreign coal provoked locational changes of the centre of Spanish iron production.

A third aspect -to underline for Spanish iron production is that throughout most of the nineteenth century traditional methods coexisted with more modern installations. We find wrought iron production in Spain by direct processes —Catalan forges and sponge iron methods— with a high presence up into the 1870s. The high grade of ores in Biscay allowed producers in north-eastern Spain to postpone the adoption of coke blast furnaces and puddling works and introduce transitional 'modern' direct processes such as Chenot and Gurlt-Tourangin which produced sponge iron instead.[5] As in the case of Sweden —based on a very similar ore specificity— more traditional techniques were able to survive over a longer period of time than in most other European countries. These adapted traditional processes provided a product of higher quality, which was more suitable than puddle iron in "markets where metallurgical technology was little developed, […] [and where these traditional products were easier to transform] than puddled iron to treatment by simple work-up techniques."[6] The specificity of Biscayan ores and the low degree of market integration thus retained direct processing methods in the north-east of Spain during the first three quarters of the nineteenth century.

A last recurring pattern to be observed all throughout the nineteen century is the use of foreign engineers, technicians and workers —or national counterparts educated in the iron and steel centres abroad. Their skills were needed especially for setting mills up, which involved calibrating the different processes with the existing raw materials, and running them in their initial phases until they had transmitted enough analytical skills the professionals they had been matched with.[7]

Establishing and running modern integrated mills in Spain

This part of our study will provide a systematic analysis of the performance of the early phase of modern Spanish integrated iron and steel mills, i.e. from the mid-1880s until the Spanish Civil War in 1936. The main issue is to determine whether or not Spanish iron and steel products were competitive or might have been so. Identifying which products Spain had a competitive advantage for and how it maintained, increased or lost this advantage over time will provide evidence of this. We will find that Spain was competitive in ore intensive products and that its competitive margin decreased as products became more coal intensive. Even products which we identify with a high profit margin suffered a downward trend during this period indicating the necessity for firms to find strategies to maintain or increase competitiveness.

Spain's role in world iron and steel production from the last quarter of the nineteenth century through the early twentieth century had been that of an iron ore supplier. The importance of Spanish iron ores grew with the scarcity of low-phosphorus ores in countries with high demand such as Great Britain, Germany and Belgium. The liberalisation of Spanish mining legislation in 1868 had helped remove some of the legal barriers on property rights, commerce and investment. And finally, the exploding Bessemer steel rail demand in the last quarter of the nineteenth century provided incentives and opportunities for expanding mining activity in Spain. The ores being mined in Spain were mainly hematite —low phosphorus— the only type of ores that Bessemer steel could be made of. Around seventy percent of the iron ores extracted in Spain between 1876 and 1936 was hematite ore mined near the north coast, in Biscay and the Santander Province. Both regions had the cost advantages of coastal proximity and low-cost open cast, i.e. surface layer, mining. This set of circumstances helps explain why Spain mined an average 8.05 % of world iron ore between 1882 and 1922.

Spain's small but relevant role as an iron ore provider, comparable to that of Belgium or half of that of Germany, did not carry over to the further transformation of iron and steel, where Spain's total industry produced a mere 0.69 % average of total world output over the same time period. Especially knowing that Spain had fair sized coal reserves moderately close to Biscay's rich ore deposits, it is hard to understand why ores were exported and why Biscayan entrepreneurs conformed with their meagre role in world iron and steel production. Spanish contemporaries were well aware of the industry's potential comparative advantage and even modern day economic historians have maintained the hypothesis of lost opportunities in the Spanish iron and steel sector.[8] Its failure has been attributed to the lack of internal demand, e.g. railways were built using mainly foreign iron and steel exempt from duties, or the existence of high levels of protectionism which sheltered the sector from the efficiency of world economy and instilled the associated mechanisms of rent-seeking and conforming with captive home markets.[9]

A correct assessment of the opportunities Spanish industry had, demands a comparative analysis both in time and space. Indication of the industry's potential may be reflected by the early attempts made by foreigners to set up processing plants on Spain's coal fields in Asturias. Cockerill's failed enterprise in 1832, the British venture initiated in 1844 in Fábrica de Mieres, and two other French ventures in the second half of the century were slightly more successful.[10]

The Third Carlist War (1872-1876) and the social and economic turmoil it caused, especially in northern Spain, prevented a second wave of projects to install iron and steel mills in Bilbao in the Bessemer steel plants' boom years. Processing ores to steel on ore sites had become feasible with the succession of innovations made to the Bessemer steel making process. The idea of processing ores to pig iron and steel in Bilbao and shipping coke or coal as a return freight became an important strategy to consider with the possibility of processing pig iron directly to steel with no cooling down, analysing and remelting.

The Bessemer process itself removed remaining impurities from pig iron in a 15-minute interval with virtually no coal or coke. Its resulting steel quality depended very much on pig iron input. Until the 1870s, hematite pig iron was cooled down, analysed and combined to be remelted in cupola furnaces in order to obtain the adequate mixture for converter processing. Starting in the mid-seventies, iron masters in France and Belgium calibrated blast furnace input and monitored furnaces carefully enough to directly obtain the adequate mixture of pig iron for Bessemer processing. Pig iron ran out of the furnace into ladles and was poured straight into preheated Bessemer converters with no reheating coal requirements. This technique was adopted quickly by English and American works.

Among others, "Krupp was very impressed by the news Alfred Longsdon [Krupp's English partner] brought him from England about the successful implementation of the process [direct Bessemer processing from the blast furnace: Wengenroth's note] and he proposed constructing blast furnaces in Essen, or, as a radical alternative, erecting a completely new works [Blast furnaces and Bessemer works: note author] in Spain on his iron mines there." [11] Lower transport costs gave British firms processing Biscayan hematite ore a clear advantage over Krupp, especially because they paid lower freight rates and many of them were located on coastal coal sites, which allowed them to send return freights. This is what motivated Krupp's project of building a plant with six blast furnaces in Bilbao to process and ship out pig iron as a return for the coking coal sent from Germany used for the furnace. Krupp's saving per ton of Bessemer pig iron was calculated to be £ 3.9s.3d. or more than a 40 % saving in 1873. A financial strait at Krupp in 1873 hindered the project from being put into practice and by 1878, when it was reconsidered, savings had been reduced to 1 ch. 6 d. —a negligible difference which was more than compensated by set-up costs and acquired expertise in Germany. The considerable drop in freight rates was responsible for the loss of opportunities.[12]

In 1871, the Bilbao River and Cantabrian Railway Company Limited –a subsidiary of John Brown Co.— bought plots in Sestao (Bilbao) to construct blast furnaces and process iron ore from the nearby Galdames mines they owned, transported by a factory owned railway they started building that same year.[13] The railway was finished in 1876 and blast furnaces had been completed in 1873. The political climate —the third Carlist War [1873-76] and its aftermath— was one of the reasons which motivated the company to abandon the blast furnace project and sell the installations to the Duke of Mudela —Francisco de las Rivas— in July of 1879. The second and more important reason for selling its processing plant was the fact that ore deposits in Galdames were significantly less than prospected. Mudela's nephew and mine owner —José María Martinez de las Rivas— took on the management of the completed iron works and the furnaces were finally fired up in October of 1880. The new company, San Francisco de Mudela, profitably produced and exported Bessemer pig iron until the end of the century.[14]

These two projects show that foreign entrepreneurs coincided at some moment with Spanish contemporaries in identifying potential profits from hematite pig iron and steel production in Spain. Nonetheless, from what we know, foreign capitals concentrated on safeguarding their ore supplies by buying or participating in mining companies rather than investing in processing plants in Spain. Charles Cammell and John Brown invested in mines in Galdames near Bilbao, Bolckow, Vaughan & Co. had invested in Luchana Mining, Consett, Dowlais, and Krupp in Orconera Iron Co. Ltd.; Cockerill, Denain and Anzin, and Montataire in Société Anónyme Franco Belge des mines de Somorrostro.[15] During this period, foreign investment in mining seems plentiful whereas investing in processing abroad was scarce. One important reason may be the limited size of home and regional markets in countries like Spain, as pointed out by Chandler.[16]

But combining reasoning with empirical observation, we can contrast if processing in Spain was a feasible strategy for foreign firms versus shipping ores to their home production sites. Basic technical coefficients and the existing freight rates data for ore and coal are instrumental for these calculations. Primary processing of ore to iron in coke blast furnaces used approximately two tons of Biscayan ore and somewhat over a ton of coke.[17] For the moment, we will assume Spanish coal inappropriate for coking and processing purposes, this assumption will be reconsidered further ahead. Differences in freight rates for coal and ore would be negligible, but we have introduced an important adjustment in the existing data: Coal freights have been multiplied by 1.4 to obtain the equivalent coke freight. [18]

Note that for a foreign firm there are two ways of obtaining 1 ton of pig iron: a) shipping home two tons of ore for processing, or b) shipping a ton of coke to Bilbao for processing the two tons of ore there and then shipping home a ton of pig iron. In both cases two tons of freight must be paid. Table 1 below, shows the available freight data for ore and coke from Spain and to Great Britain and vice versa, respectively. Coke freights are an average 18 % higher than ore freights using Prados' data, which makes processing in Spain more expensive. If we take into account that freight rates for pig iron or transformed products were even higher than for coke or ore, as higher value-added products suffer higher freights, which was the case of pig iron, transport cost seems to have determined foreign location.[19] Other considerations might be the deterioration, moisture and disintegration coal and coke suffer from handling and shipping which also contributed to making the Spain site strategy less attractive. Summing up the original question, we can say that processing ores to pig iron in Spain rather than northern Europe would have been more costly according to the evidence and notions we have used.[20]

One interesting aspect of this discussion is whether or not freights for company owned ships could have changed the whole scenario back in favor of Spanish processing plants. Definitely this is relevant because the Ybarra plant set up in 1856 bought steamships to carry its coal and coke to their factories from Great Britain as early as 1862. There was then a feasible strategy which annihilated the value added price discrimination on freights we have considered before.

The exercise below has been useful to explain why foreigners preferred exporting ores rather than processing them to pig iron in Biscay assuming that freights could not be integrated or internalised, but this still leaves open two questions: why foreign capitals did not set up integrated steel mills once direct processing of pig iron became an option and why Spanish investors did float modern mills in Biscay after the Third Carlist War. Establishing the efficiency or competitiveness of the mills' products will validate the economic rationale of investments in a period of low protection and limited home markets.

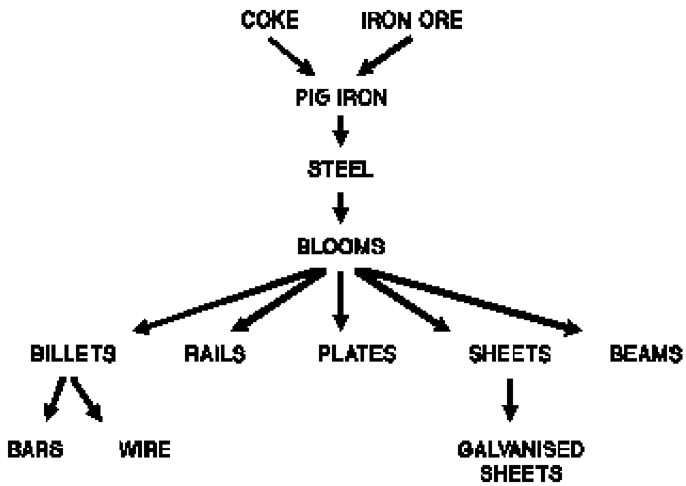
Table 1
Iron ore and coke freights from Bilbao and Great Britain. [Shillings GB].

Years	ORE			COAL (Coke equivalent)		
	Harley Bilbao to NE GB	Escudero Bilbao to Middlesbrough	Fairplay-Prados Bilbao to Middlesbrough	Harley Wales to Bordeaux	Prados Newport/ Cardiff to Bilbao	Fairplay Wales Genoa
1871-1875	15.4	n.d.	14.2	13.9	11.8	22.8
1876-1880	10.2	8.7	9.6	11.9	10.2	19.3
1881-1885	7.0	7.1	7.1	10.5	8.1	n.d.
1885-1890	5.9	5.7	5.9	8.7	6.9	13.9
1891-1895	5.1	5.5	5.1	6.6	5.9	9.7
1896-1900	6.0	6.1	6.0	6.9	5.4	12.2
1901-1905	4.6	4.4	4.6	5.5	6.4	8.4
1906-1910	4.3	4.4	4.3	5.9	6.2	9.2
1911-1915	5.3	7.3	7.8	8.0	11.9	24.1
1916-1920	n.d.	21.0	26.8	n.d.	n.d.	110.6
1921-1925	n.d.	7.5	n.d.	n.d.	n.d.	n.d.

Sources: Harley (1989), pp. 334-7; Prados (unpublished); Escudero (1998), table A.15; Fairplay (1920).

The analysis will concentrate on two Spanish mills, Baracaldo and Sestao, because they are technically the most advanced mills. The Baracaldo mill had been designed and constructed by E. Windsor Richards at that time the managing director of Bolckow Vaughan and the Sestao mill had been designed and constructed by the Belgian Societé Anónyme Cockerill. Between the two of them they concentrated more than 50 % of pig iron and steel production in the period we are considering and they provide the data necessary for applying a thorough examination of the questions we have put forward.[21] The company they both merged into in 1901, Altos Hornos de Vizcaya, has preserved the minutes of the board of directors and annual shareholder meeting memoranda from the origins of both companies. Annual data has been put together from this information from the mid 1880s on, and monthly cost accounting for most of the production lines are available from 1897 to 1923 for the Baracaldo mill —Altos Hornos de Bilbao— and from 1901 to 1923 for the Sestao mill —La Vizcaya.[22]

Chart 1
Simplified production flow chart

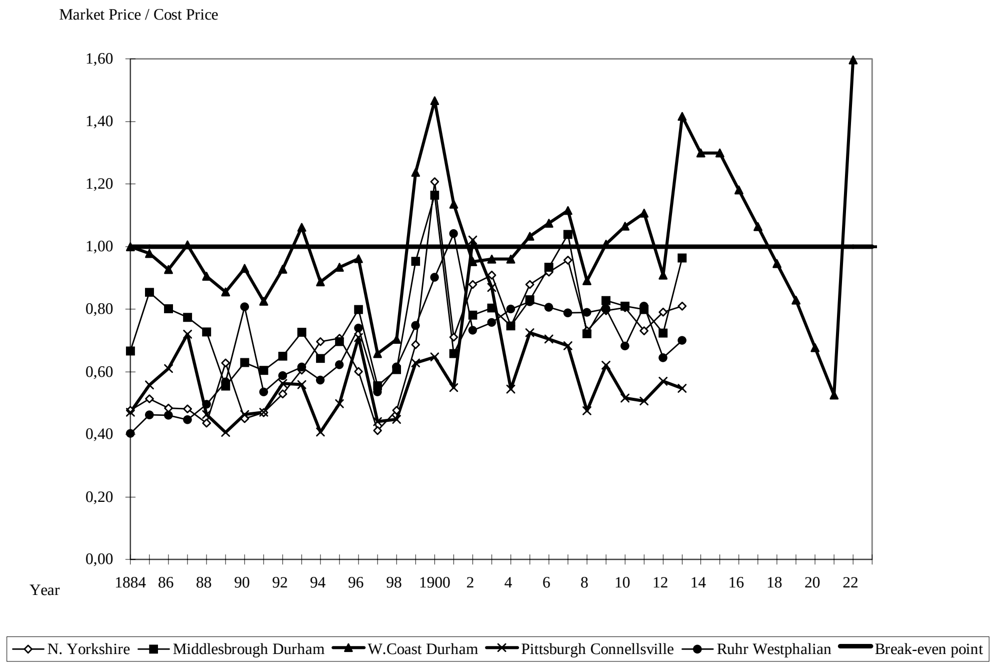


The flow chart above shows the inputs and products in their sequence of transformations. Discussion of iron and steel production will follow this same order. A first approximation to establishing the degree of competitivity of the mills will be confronting Biscay mills' cost prices with foreign market and export prices. Although this is a rather rough approximation, it avoids some of the problems related to the comparability of cost estimation, of product quality, of the inputs being used, etc. A second approach will be Total Factor Productivity calculations for these companies compared to those available for Germany, Great Britain and the United States of America.

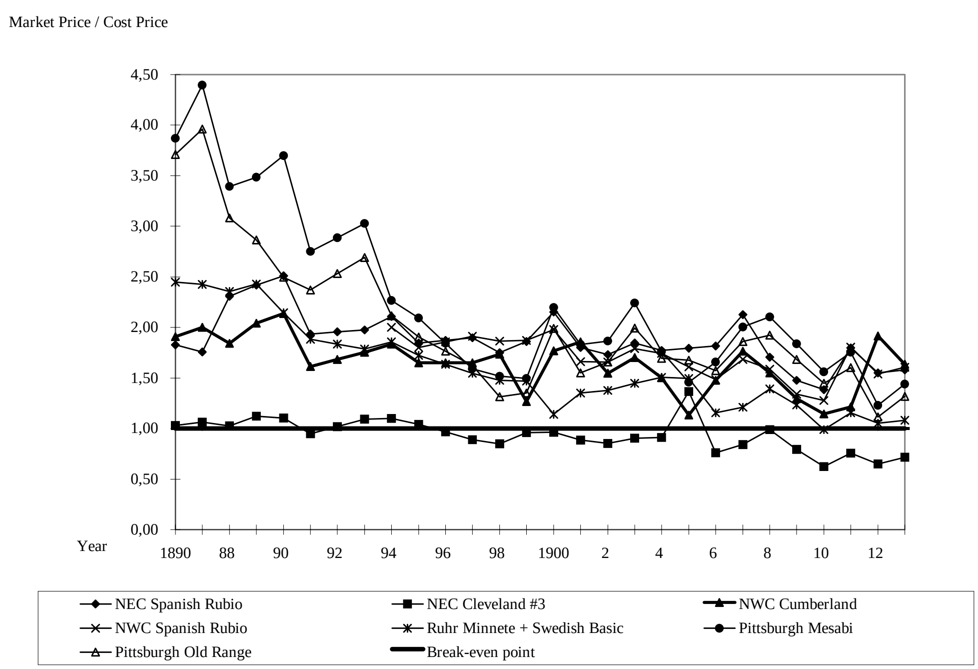
Starting from the top of the chart. Obtaining pig iron is the first transformation process that needs to be examined. Coal and ore are the primary inputs in processing iron ore to pig iron. Even today over 80 % of the costs of reducing ore to iron can be attributed to these two inputs. Graph 1 and 2 relate the factory cost prices of iron ore and coal respectively at Biscayan mills to market prices on some of the major world markets at the time. The graphs show ratios between market prices abroad and home factory cost prices. Values below the break-even point —one— indicate that the cost price in Biscay was above that particular market price abroad. Whereas values above one show how much lower the cost price was, compared to market prices abroad, i.e. a 1.85 ratio for Cumberland ore on England's North West Coast markets indicates that Cumberland ores were 85% more expensive on that market than the ore delivered at factory gate in Bilbao.

Coke freights from abroad to Bilbao definitely were taking off some of the competitive edge which Bilbao producers had with respect to their ore prices. Both of the Spanish mills imported coal and coke mainly

Graph 1
Coal price ratio.



Graph 2
Iron ore price ratio.



from Great Britain and Germany. With the exception of Durham coke sold on the British West Coast, Bilbao factory cost prices for coal were generally above market prices on locations for the foremost competitors on international markets, i.e. north-west and northeast coast works in England, Ruhr works, and Pittsburgh works. Coal prices came down for Bilbao producers at the beginning of the century, relatively speaking, but with the exception of Connellsville coke, all other ratios remained between 0.6 and 0.8, i.e. coal was between 66 and 25 per cent dearer at factory gate than on major market places such as the Ruhr, Pittsburgh, Middlesbrough and Northern Yorkshire markets, which all had production sites near to coal fields.

The coal cost prices for the Spanish factories we are examining can be considered near optimum, as the process of contracting foreign coal was fairly efficient. Bilbao producers had contracting agents in the Tyne ports and generally signed annual contracts when prices there were lowest. The prices shown here are contract prices, which we have obtained as weighted averages from references in the Board of Director Minutes for both factories between 1884 and 1923.[23]

Just as access to coal was definitely not a strong point for Basque producers, Bilbao did have a large price advantage in ore procurement. Original prices have been adjusted for different ore yields.[24] The Bilbao mills started off with a clear price advantage in iron ore at the end of the nineteenth century.[25] Biilbao ores' cost price was over four times lower than Old Range and Mesabi ore at market prices in Pittsburgh around 1887 and stayed around twice as cheap as ores at north-east and north-west coast markets in Great Britain. The trend for this price advantage was downward as the new ore fields were increasing extraction, i.e. Lake Superior, Lorraine, Sweden, and given that Bilbao and Santander ore fields were depleting at the same time.

As we stated earlier we are concerned with pig iron production which combines coal and ore to a crude iron. Table 2 augments our first perceptions of pig iron production by comparing cost structures for various sites in 1897. The sites quoted in France, Belgium, Germany, Great Britain and USA paid over and around 60 percent of their total costs on ore procurement. These were coal sites, and bringing ores from outside was much more costly than the coke employed for processing it, which they had on their sites. Bilbao shows the opposite picture, over 50 percent of its total cost was spent on using coke from abroad.[26]

Table 2
Pig iron input costs in 1897 given in percentages.

	Ore Cost*	Coke Cost*	Flux Cost*	Labor Cost*	Others Costs*	Cost Price Shilling
Loire	65.8	23.4	2.6	5.6	2.6	54.5
Liege	60.4	27.4	2.8	6.6	2.8	50.0
Westphalia	61.2	26.8	2.9	5.7	3.3	49.3
Cleveland	60.6	26.8	4.0	5.6	3.0	46.7
Pittsburgh	70.7	16.0	4.0	6.7	2.7	35.4
Bilbao	29.8	53.1	3.8	9.5	3.8	37.3

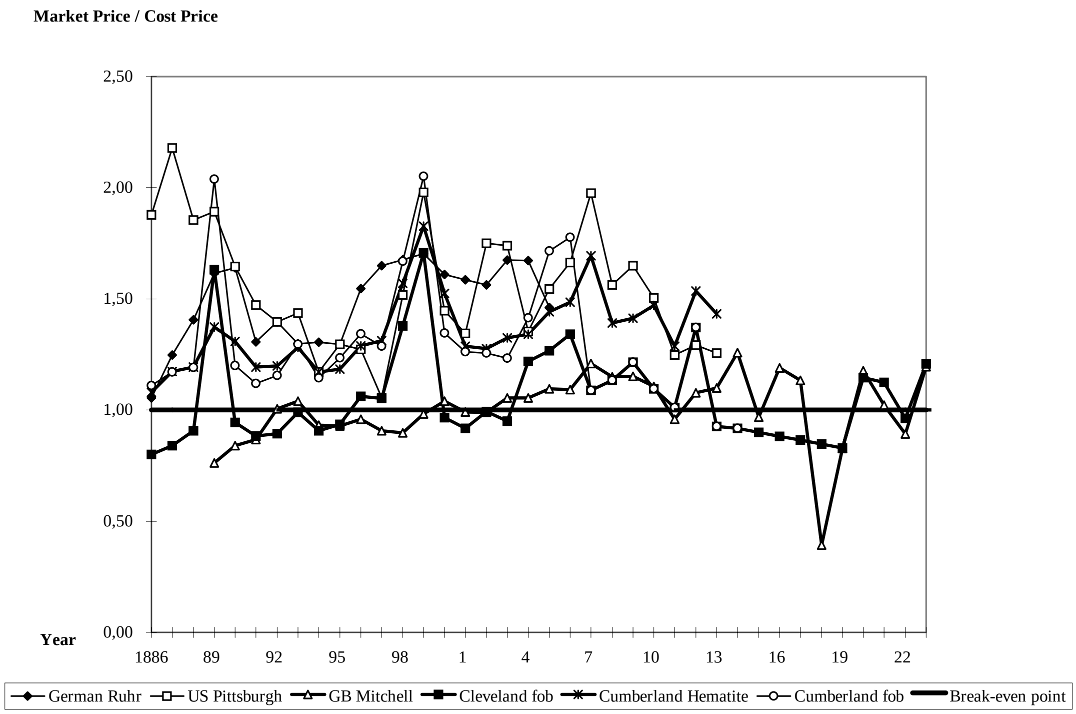
Source: calculated from Rodríguez Alonso (1902), p. 155. * the total spending on each factor as a percentage of the total cost.

Relating this back to Graphs 1 and 2, we can underline that the initial potential for comparative advantage in Bilbao lies in ore versus coke proximity. Whereas coal sites will be less competitive in the primary transformations of ore because these are more intensive in ore than in coal. The opposite is true for ore sites, they will be very competitive in primary transformations and less and less competitive as the proportion of coal employed, directly and indirectly, increases in the consecutive secondary transformations.

According to this, we would expect Bilbao producers to be competitive producing pig iron and steel products with a low coal processing content. For a rough notion on how much coal the different products consumed we can go back to our flowchart. Processing ore to pig iron in Bilbao in 1897 consumed 1.11 tons of coke plus 0.14 tons of coal, which is equivalent to a total of 1.69 tons of coal.[27] Steel summed a total of 2.4 per ton, steel blooms around 2.9 t. Heavy rails added up a total of 3.4 tons per ton. Billets contained a total of 3.8 tons of coal per ton produced and commercial bars up to 5.6 tons. Each stage of additional transformation increased the total amount of coal consumed as further heat and energy were applied in processing.

The average margin of price ratios shown in graph 3 gives a good picture of Bilbao pig iron's competitiveness with respect to other world pig irons, it was between 10 and 50 per cent cheaper than market prices abroad. Some care should be taken when interpreting comparisons between these different data sets. Obvious reasons are the heterogeneous character of their sources but also more technical reasons. Pig irons vary in their chemical composition. Even on one specific site a variety of qualities can be produced according to inputs, speed, pressure, temperature and flux used in the furnaces.

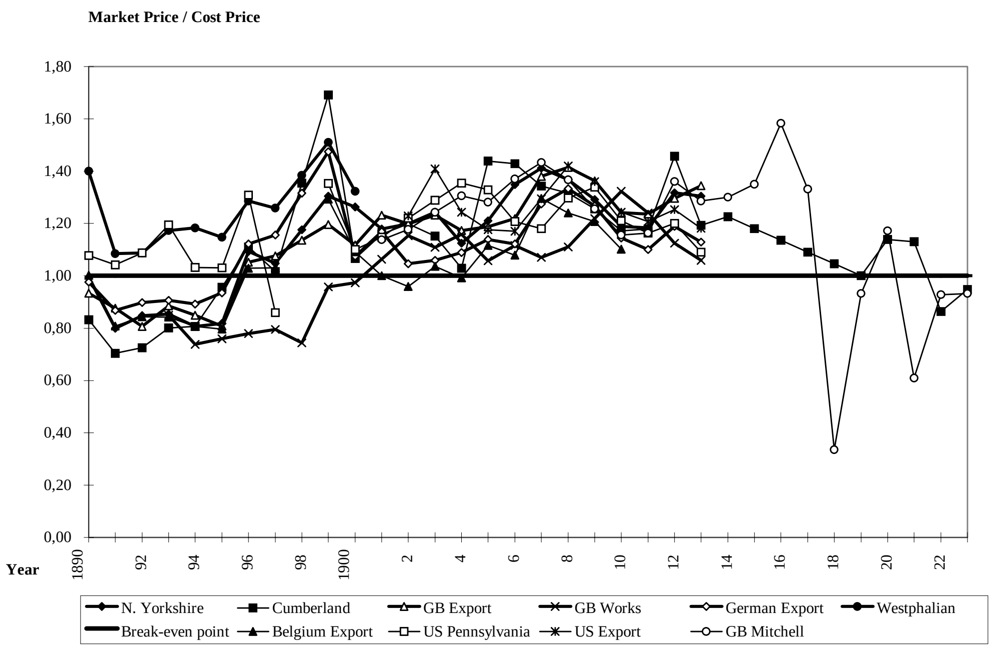
Graph 3
Pig iron price ratio.



Additional care must be taken as all Bilbao cost prices used in this paper exclude capital costs. This is common in most accounting practise up to the very end of the nineteenth century. Spanish cost prices are therefore biased downward and this reduces the real margin they have for competing in international markets — even more than we can see in the graphs. Even so Baracaldo's average cost prices come pretty close to Cleveland's market prices throughout the period. Given that Cleveland # 3 is the cheapest pig iron to be obtained at the time, shows Bilbao pig iron as very competitive especially if we consider its superior quality which makes it suitable for Bessemer steel processing opposed to Cleveland pig which was suitable for foundry iron only.

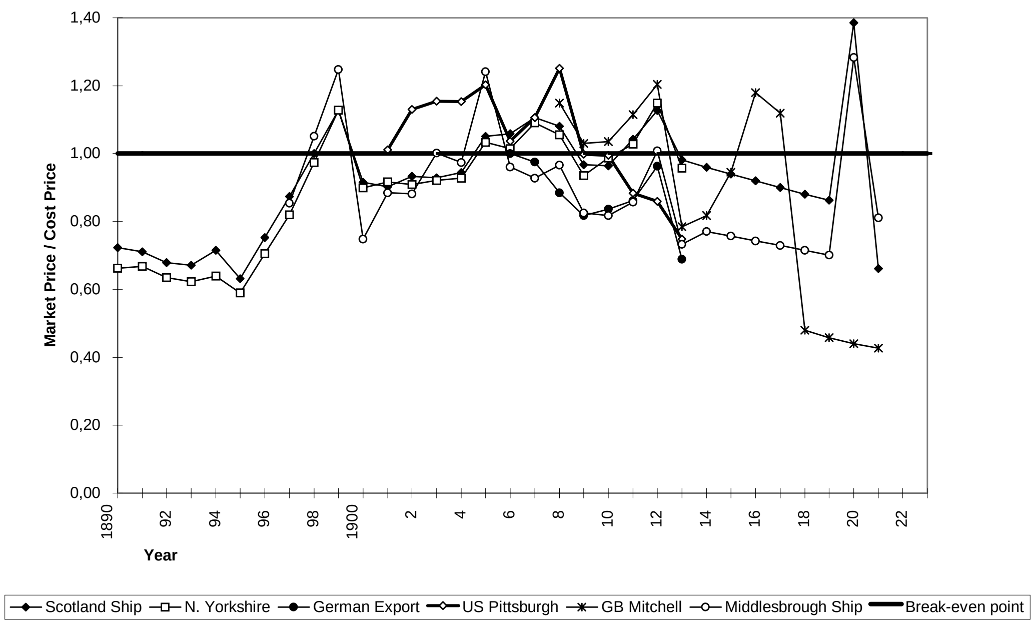
The next most important iron product in terms of assessing competitivity were steel rails. Heavy steel rails were among the more important secondary steel transformations being sold until World War I. They were a fairly unsophisticated secondary product which could be produced with a relatively low amount of coal [3.4 t in Baracaldo in 1897]. We find that Bilbao rail cost prices remain below the market prices of competing sites assembled in graph 4. Cost prices in Bilbao had a 20-40 per cent margin over market prices elsewhere. Whereas pig irons were not strictly comparable due to different chemical compositions, heterogeneity in chemical content is less pronounced for steel rails. They do tend to have numerous profiles and sizes and higher prices will often reflect smaller batches of production and greater diversity of profiles rather than necessarily a higher material cost. This can be attributed to economies of scale, higher throughputs and less hold-up times changing rolls. Even if small batches and diversity of profiles were the case of Spanish rails, we can still identify a competitive margin for them.

Graph 4
Rail price ratio.



Graph 5 reflects the downward trend in competitiveness as the transformation of steel increases. Plates in graph 5 indicate cost prices near to market prices reigning abroad, with the exception of 1905 which is subject to special circumstances.[28] Although cost prices improved with respect to market prices, the margin for putting Spanish products on foreign markets was very low and tended to decrease over time. The data collected for steel sheets would reveal a similar picture. Sheet cost prices improved relatively speaking compared to market prices abroad, but not enough to compete and possibly not enough to keep foreign products out.

Graph 5
Steel plate price ratio.



A second conclusion would then be, that for Bilbao low coal costs were key to competing in international markets. Spain's natural advantage lay in its cheap and high quality iron ores. Its disadvantage was its distance from markets and the cost of foreign metallurgic coal. The first of these problems could not be overcome. Although important changes in transport made reaching markets relatively speaking less expensive, distance as such could not be undone.

A second way of interpreting ratios between sales prices abroad and cost prices in Bilbao is taking the sales prices as proxies for unit cost prices. Long-term trends which include the effects of dumping practices and overcapacity may justify these weak proxies. Following the analytical framework presented by Allen (1992) we could then explain the observed price differentials as the result of a technical efficiency effect, an input price difference effect and —as a residual— a wrong input mix effect. The necessary assumptions are sustainable in the context of our analysis. The industry of one country minimizes costs, labour and capital are combined to make value added and various other materials are combined in fixed proportions in both countries.

This second approximation to competitivity would then be calculating total factor productivity and input price indexes for the Spanish mills, and comparing these with the existing data for Great Britain, Germany and the United States in terms of identifying the origin of price differences. The methodology used is the same as

Allen (1979, 1992). Output is measured as the tonnage of final iron and steel products, labour as the number of employees, capital is installed horsepower, the wage rate is the average annual earning per worker and the price of capital is the rental price of capital services. The table below shows input prices on different locations versus Bilbao and calculates an weighted index for inputs according to their cost participation.

Table 3
Input price difference index 1907 calculated by using Cobb-Douglas function.

Inputs in US$	Wage per year	Rental price 10 HP	Metal input price	Fuel price	IPD Index
Pittsb. Bess.	679	456	9,69	2,85	1,000
NE Coast Hem	412	308	7,77	3,80	0,783
Span. Hem. Average	255	627	5,26	4,60	0,624
Sestao	281	627	5,26	4,60	0,639
Baracaldo	233	627	5,26	4,60	0,611

Sources: Allen (1979) and (1992), Houpt (1998).

Weighted input prices are significantly lower for Great Britain's north-east coast data and the data we have for Bilbao than for the cost minimizer in 1907-9 which was the United States.[29] Wages, the rental price of capital and the price of metallic input are all lower than Pittsburgh Bessemer inputs. This cost advantage is compensated by a higher productivity in the US. The technical inefficiency results —measured in terms of total factor productivity— for the Spanish mills under examination versus the industries analysed by Allen are shown in the table below. Table 4 shows Spanish mills with a total factor productivity similar to that of Great Britain's iron and steel industry and 14 points below that of Germany and the United States.

Table 4
Technical efficiency of Integrated Steel Production measured in TFP.

	Great Britain	Germany	United States	Bilbao Mills
Production	12.418.000	12.050.361	25.643.871	262.066
Employment	261.666	170.614	303.823	5.260
Horsepower	1.383.586	823.822	3.274.400	29.061
Output per worker	47,5	70,6	84,4	49,8
Output per horsepower	9,0	14,6	7,8	9,0
Horsepower per worker	5,3	4,8	10,8	5,5
TFP	1	1,15	1,15	1,01

Sources: Allen (1979) and (1992), Houpt (1998).

And finally, coming back to the earlier part of this section we could also run a similar study on technical inefficiency leaving aside primary transformation and concentrating on steel processing and rolling. Table 5 summarizes TFP calculations for steel and rolling mills for Spain and the United States. The differential increases to 12 points with respect to the United States in 1889/90 is down to 8 points by 1899 and rises to 18.4 points by 1909. This confirms our perception of Spanish comparative advantage being embedded in ore intensive products.

Table 5
Technical efficiency of Rolling Mills measured in TFP.

Mills	Year	*Q/L*	Q/K	Q/M	Q/M	A_{time}	A_{sp}/A_{us}
Spanish Mills	1890	31,42	7,85	0,57	279,91	0,89	
“	1899	36,65	6,13	0,71	226,95	1	
“	1909	30,98	6,71	0,65	293,35	0,94	
“	1919	20,27	3,10	0,55	218,05	0,72	
US Mills	1889	43,96	11,54	0,788	24,72	0,94	0,880
“	1899	61,03	9,99	0,7893	24,8	1	0,920
“	1909	73,130	9,08	0,823	25,64	1,06	0,816

Sources: Allen (1979) and (1992), Houpt (1998).

Estimating the effect of a wrong input mix in Spain is a more complicated matter. Given that both of the Bilbao factories were designed by foreign engineers using the same mineral ore in their own installations we can assume that the Spanish mills were operating close to best practice. That would lead us to conclude that Bilbao mills had a reasonable input price advantage over German, British and American producers and had a lower productivity than German and US mills but equalled that of Great Britain. After 18 years of high protectionist tariffs they maintain a fair level of productivity. The previous patterns of competitivity in ore intensive products are also confirmed by this exercise.

Changing coal dependency

Coal provision did have solutions. Two strategies were available: on one hand, home coals could be used to replace foreign coals. This was a feasible strategy in Spain, which, as we have mentioned before, had important coalfields off the north coast moderately close to Bilbao. On the other hand, all throughout the late nineteenth century and the early twentieth century technical changes were being introduced to reduce the waste of energy in the use of coal and which were directly improving the efficiency of coal consumption.

The replacement of coals from Great Britain and Germany with national coal and cokes requires us to reconsider the initial assumption that Spanish coal was inappropriate for coking and iron processing purposes. Fraile (1982) has assessed the difficulty of substituting foreign coke and coal with Spanish inputs. Cheap return freights on iron ore ships going from Bilbao to 'coal sites' in Great Britain and Germany and infrastructure deficiencies in Spanish coal mines made home coal and coke comparatively more expensive.

Asturian coal, the most abundant of Spanish coals, was a most obvious candidate for use in Bilbao. It was geographically close, around 300 km to the west along the Cantabrian coast. But Asturian coals held a number of problems. Perhaps most important of all, they were difficult to mine. There were no potential scales, quality improvements or productivity gains to be obtained from increasing the scale of coal mining activity. Whereas the coal seams being mined in Europe and USA averaged over 1 meter in width, Asturian seams varied between 50 and 60 cm and their width oscillated considerably[30]. Lean seams proportioned an inferior volume of coal per meter of stall advanced and made mechanisation far less economic. A second obstacle to improving mining techniques was the irregularity in coal quality and the high proportion of seams —56 per cent— with fallings over 60°.[31] The lack of coal homogeneity and the low level of mechanisation in the mines determined low quality and Spain's high pithead coal prices, to a great extent.

Generally there are other considerations in the substitution process which are of more interest to the metallurgic blast furnaces consumers. These are coal pureness, a high coke porosity to permit penetration of ascending gases in the furnace, oxygen feed and a large burning surface; a certain stability to allow for stacking blast furnaces high; resistance to abrasion; reaction with carbon dioxide, just to name the more important properties required.[32] Impurities included in coal, lower the caloric and reduction yields substantially.

Given the complexity of the tradeoffs between coke properties, the exact composition of the materials introduced into the blast furnace was generally determined empirically by trail and error, establishing an optimum mix or formula. After factor proportions had been established, the quality of inputs needed to remain constant for optimum output results. Minor quality variations could seriously soot or even damage furnace linings and spoil the pig iron produced. In the case of the two Bilbao factories studied, avoiding these input quality variations led to mixing coals and ores in deposits to even out irregularities previously. In many cases they reduced additional risk of quality variations by including special clauses in supply contracts or ultimately by backwards-integrating into a coal and ore mines.[33]

A price rise in 1889-91 had given way to considering experiments with Spanish coke. In Baracaldo's factory director, Mariano Zuaznavar, abandoned his management position to promote a 317-km railway which was to link another coal mining district in León to Bilbao. By 1894 Victor Chávarri, founder and *alma mater* of the Sestao factory was promoting coking coal mines in Asturias. Large proportions of Spanish coal were being used around 1897 as home coal and coke became cheaper in relative terms.

As early as August of 1897, given the serious damage Asturian coke had occasioned in the blast furnaces, the Baracaldo managers renegotiated original coke contracts with Spanish proveyors into equivalent heating and steam coal contracts. Mr. Lançon, Director of the neighbouring San Francisco de Mudela factory inspected the damaged furnaces and came to the following conclusions: the use of fragile, breezy coke had covered the linings of the furnaces with coal dust, slag and iron. The process of removing this would be lengthy. Two of the furnaces were fired with a special charge for more than a month. The economic loss was calculated in over Ptas 80,000.[34]

By early 1898, the other firm, La Vizcaya or the Sestao factory, was suffering low productivities in both of its blast furnaces and introduced changes in furnace design and blast temperature to re-establish previous output levels. A further drop in pig iron yield in September and November opened a technical investigation. The report stated poor coke quality as the primary cause of reduced productivity, especially the lower per unit energy content. During the following year the board of directors minutes mention, not only of the poor performance of the blast furnaces, but also delays in delivery of Spanish coals, its high sulfur contents, and irregular qualities of home coking coals. As a consequence the proportion in which Spanish coals were used was reduced progressively. Spanish coke continued being added in low proportions to bring costs down, but Spanish coal found application mainly in soaking pits, steam ovens and Siemens ovens. Both factories attained a notable saving in per unit coal consumption. Technical change at that time was in processing steel and steel products, and both had high potentials for saving coal.

Our most important results concerning the substitution of foreign coals are twofold. The technical difficulties both factories found in replacing foreign coking coal, an attempt which both factories had abandoned except for a tolerable percentage by the turn of the century. And secondly, technical innovation which reduced the consumption of coal. Concerning the first point, we can add that both factories did obtain some savings by installing coking facilities and buying foreign coking coal rather than coke. Relating to the second point we observe a strong diminishing trend in per unit coal consumption in the processing of steel and steel products, pig iorn processing itself did not seem to have apparent savings.

Reassessing the role of Spanish steel.

We have been able to trace some of the iron industry's earlier backwardness in adopting new technologies to the input specificity of northern Spanish iron ores. The high quality of iron ores in the north of Spain allowed pre-industrial techniques to survive well into the nineteenth century. The Bessemer age clearly reversed this situation. Northern Spain's ores became most appropriate for industrial mass steel production after 1862. Historiography argues that foreign investment simply absorbed the major part of the northern mines to guarantee their Bessemer ore supply. We have been able to show how falling freight rates had reduced the incentives to establish blast furnace mills in Spain to process ores to pig iron using coal freights as a return for this intermediate product.

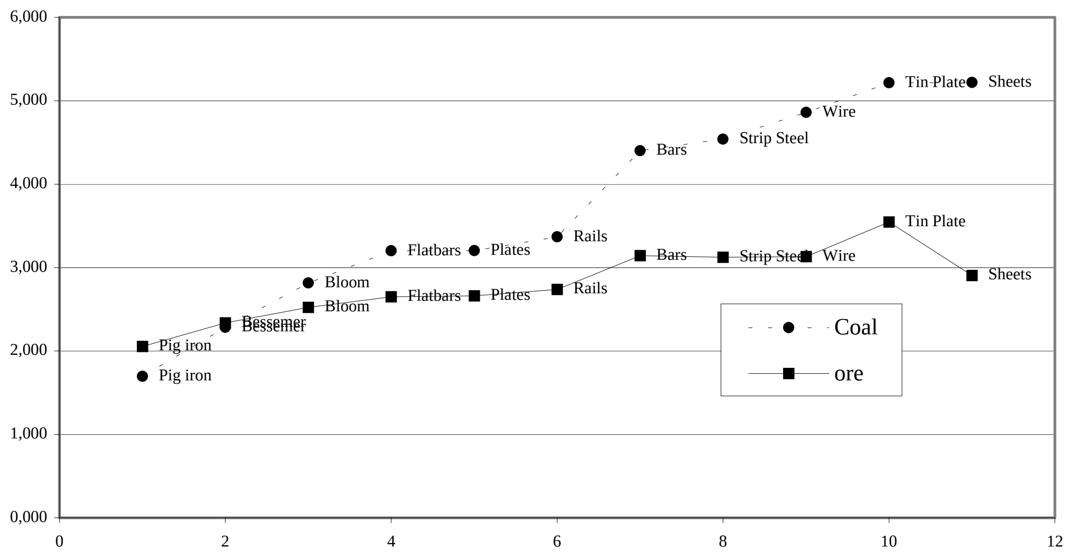
The maturity of the Bessemer process, which introduced direct processing straight from hot pig iron and hence reduced the amount of coal contained in final products, changed this original strategy. Complete processing in Spain became an option to consider. Surprisingly none of the modern mills established during the 1880s made much headway in this direction. Three mills had been set up respectively by the three dominant local mining groups. Two of these, San Francisco de Mudela and La Vizcaya, originally oriented an important part of their product to foreign markets. Nonetheless there were certain ranges of products which became competitive in a *ceteris paribus* context —those intensive in ore or little intensive in coal.[35]

We have left an important part of the story to a side by not considering demand factors. The expansion of production capacity in Europe and the United States throughout the end of the 19th century sharpened competition and depressed prices by the mid 1880's. To what extent depressed world markets made Spanish producers turn to home markets, rent seeking and protectionism in the late 1880s and the following decade has not been contrasted here. Later steel processes —Thomas and basic open hearth— capable of using low quality ores and scrap may have sentenced this opportunistic behaviour by condemning Spanish steel to that of an inefficient home producer protected by tariffs.

With the indications, we have Spanish steel had a comparative advantage on world markets as long as they were ore intensive. Graph 6 shows the tons of coal and ore accumulated in different iron and steel products.

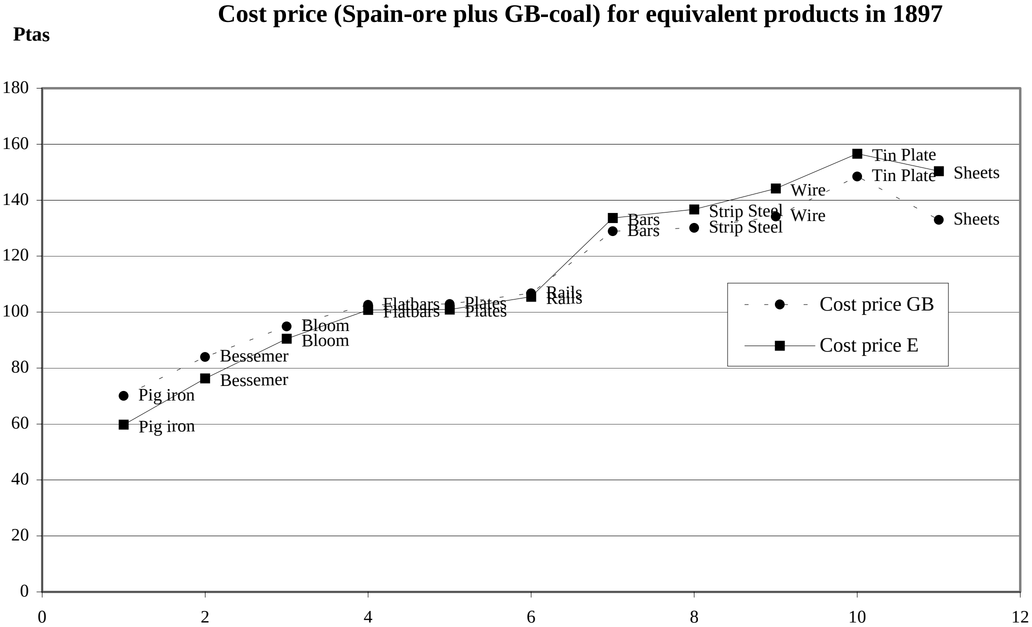
Graph 6

Tons of ore and coal consumed in Baracaldo per ton of product



Graph 7

Cost price (Spain-ore plus GB-coal) for equivalent products in 1897



Graph 7 uses those same amounts and shows the total cost in terms of Spanish ore and British coal in Spain and in Great Britain for the different products. The graph shows that for levels of transformation beyond that of rails —with a high coal consumption per ton— costs in terms of these major inputs was higher in Spain than in Great Britain.

Bilbao mills could have become world producers of pig iron, Bessemer steel, steel blooms, flatbars, plates and rails but nothing beyond that. If we combine this perception with the evidence revealed by Webb, according to which major German mills forced pig iron production to push down unit costs. They dumped overproduction, eliminated foreign competition by high effective tariffs on primary transformations —pig iron and heavy rolled steel goods— stabilised income through cartels and innovated thanks to regular income. In that story, the comparative advantage in coal intensive products worked from the centre. But, at the same time, the comparative advantage in ore intensive products from the periphery was lost in that struggle. Consequently the modern factories established in Spain in those years had little room for manoeuvring on world markets. Paradoxically they were probably forced to back out of the markets in which they could have been competitive —ore intensive products such as pig iron, steel ingots, bloom or rails— due to price dumping in other countries which was being put to practice to attain larger scales and overcome the low competitivity in ore intensive products. The comparative advantage as a governing principle for economic efficiency and a source of healthy economic growth seemed to work better for some parts of the world than for others.

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[1] See Molinas and Prados de la Escosura (1989) and Simpson (1995).

[2] Flinn (1952) and Flinn (1955)

[3] Fremdling (1982), Landes (1979), pp. 193-200.

[4] Nadal (1970), (1970a) and (1975)

[5] Uriarte (1998)

[6] Söderlund (1960), p. 60.

[7] See Houpt and Rojo Cagigal (2001).

[8] Alzola refers to exporting Biscay ores instead of processing them as "imitating Esau who sold his birthright for a mess of pottage", Alzola y Minondo (1896), p. 55. See also Adaro Magro (1885), p. 175.

[9] Nadal (1989), p. 183 "La demanda ferroviaria, menos intensa que en otras épocas, acuñó, en los últimos años del siglo XIX, el nacimiento del acero español. Esta constatación refuerza, a fortiori, la tesis de la gran oportunidad perdida treinta años antes por la industria del hierro colado y del hierro afinado, como consecuencia de la franquicia al material extranjero acordado por la ley de junio de 1855." see also pp. 158-165, and 187. Fraile (1991), p. 202 "Lo que realmente diferenciaba a España de la mayoría de sus vecinos era la proclividad del marco institucional a generar y mantener a lo largo del tiempo estructuras de oferta con un marcado carácter restrictivo y monopolista que tendían a separar a la industria española de la competencia internacional por medio de la protección arancelaria. Con un marco institucional adecuado, los empresarios industriales españoles eligieron una estrategia de maximización acorde con los precios relativos de los factores y las tasas esperadas de beneficios. Para un mismo nivel de beneficios, la facilidad de obtener rentas del estado (...) hacia más atractiva la asignación de recursos en búsqueda de rentas."

[10] Minas y Fábrica de Moreda y Gijón was formed in Paris in 1878 , and the Compañía de Asturias of La Felguera was created in Paris in 1894. Adaro Ruiz-Falcó (1968) and Memorias de Central Siderúrgica de 1924.

[11] Correspondence on the 4th of May, 1876, Wengenroth (1994), p. 90.

[12] Wengenroth (1998), pp. 4-5.

[13] The company was originally floated under the name of Bilbao Iron Ore, which it changed in 1876. Escudero (1998), p. 39.

[14] See Bahamonde Magro (1989) pp. 576-7; Escudero (1998), pp. 31-2, Montero (1990), p. 68 and Montero (1995), p. 70.

[15] For Charles Cammell and John Brown see Wengenroth (1986), p.185; for Consett, Dowlais, Krupp, Cockerill, Denain and Anzin in AHV (1902), pp. 53 and 69, Díaz Morlán (1999), pp. 82-95.

[16] Chandler (1994), p. 139, "None of the American companies invested in a plant abroad if an extensive capacity already existed in that area (...) the investment required to achieve minimum scales would have created massive overcapacity in the region in which the new plant was built." and idem, p. 491, "Like the Americans, the German steelmakers rarely built works abroad to support their marketing organizations, for the capacity required to compete with existing plants in those markets was too costly and would have increased output too much to be worth the investment."

[17] Appendix 3 of La Reforma Arancelaria (1890), vol. II, p. 400 gives an ore consumption of 1.98 mt. for pig iron production in Bilbao in 1886 and 1890. The monthly accounting data for the Baracaldo mill in 1897 show an average of 1.95 mt. consumed per ton of pig iron. Indirect methods dividing ore consumption by pig iron production give the somewhat higher figure of 2.05, but some of the total consumption of ore used in these calculations was also used in the Siemens-Martin process. Two tons per ton of pig iron seems a reasonable figure given that little technical variations were introduced in the blast furnaces that could have lowered this ratio from since they were built. The average iron content of ores mined to that date was between 52 and 56 %. Coke consumption is based on data taken from La Reforma Arancelaria (1890), Madrid, Vol. II, p. 400 for production in Bilbao in 1886 and 1890.

[18] There are two justifications to doing this, first of all, 1.4 tons of coal is necessary to produce a ton of coke, and secondly, coke freight rates recorded in company records in Biscay were on the average forty percent above those of coal.

[19] see f. i. Hoover (1948), chapter 3.

[20] We must be cautious about jumping to conclusions, coke freights might have been brought down substantially by increased shipping and higher amounts being shipped on a regular basis from northern Europe. Two-way traffic could have been coke and iron rather than coal and ore.

[21] The data set is for Altos Hornos de Bilbao [AHB] and La Vizcaya [VZC] and the company they merged into Altos Hornos de Vizcaya [AHV].

[22] This data has been averaged to annual series weighting monthly prices by their productions.

[23] The different price series for coal and coke —for both factories when this applies— for data between 1884 and 1923 can be found in appendices A and B. Appendix C shows the remaining data series which have been brought together to calculate the corresponding ratios.

[24] Allen (1975), pp. 301-2. Ore cost used is the cost of one ton of ore at the furnace divided by its iron yield, f.i. 56 % ore at 12 shilling would be 12 s./0.56 = 21.42. This is to calculate how much is spent on obtaining the amount of ore necessary to produce a ton of iron.

[25] With the exception of Cleveland ores which were the cheapest in Europe in that time period. Nevertheless Cleveland pig iron never found an equally economical steel transformation process it was inadequate both for Bessemer and Thomas converters. See Wengenroth (1994), chapter 5.

[26] Explaining why Bilbao producers did not use Spanish coal for processing will be an important issue to address.

[27] 1.11 * 1.4 [conversion rate] + 0.14 = 1.69

[28] Since 1901 the two factories whose cost data we are using formed the dominant firm on Spanish oligarchic steel markets. In 1905 and 1906 they led a price war because the cartel was dissolved and we they produced near optimal capacity which lowered cost prices during those years.

[29] The shares in costs for labour, capital, net consumption of metallic input and fuel consumption are .24, .09, .48, and .06 respectively as assumed by Allen (1979).

[30] In other countries seams of this width were considered as economically not exploitable. At the beginning of our century in France, Calais averages 1.06 m, South Wales between 0.90 and 1.30 m, Scotland 1.25 and 1.75 m, in Germany, Westfalia had an average thickness of 1 m, Higher Silesia an even higher average. Olariaga quoted in Coll and Sudriá (1987), p. 99.

[31] These inclinations are due to earth crust foldings and complicate the mechanization of work, propping of the mines and hauling out of coal. Coll and Sudriá (1987), p. 98.

[32] Reactions forming carbon monoxide were fuel-wasting because half of the thermic potential became volatile. According to Burnham and Hoskins (1943), p. 308, "good blast furnace coke contains under 9 % ash and 4 % water, and good foundry coke under 8 % ash and 4 % water.(...) About 10 % of the coke is required to fuse its own ash. The elimination of sulfur (0.8 to 1.0 %) requires about 150 lb. of coke per ton of pig iron." Freedom from breeze raised the output of furnaces per week.

[33] This was the case of a coal mine in Asturias, Hulleras de Turon, bought by AHV in 1918 which proportion one of the best coking mixtures in Spain, limestone supply was guarentee by buying the Luchana Mining Company's railway, mines and plots in 1927, and an important ore mine, Compañía Minera de Dícido, was adquired in 1929.

[34] approximately £ 2,500. Experimenting with Spanish cokes began again in 1917 due to wartime shortage of English coke coal and dominated into the Primo de Rivera dictatorship.

[35] I.e. replicating a foreign mill in Spain.